

WHAT IS CLAIMED IS

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1. A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

10 forming an active device element on a substrate;

15 forming an insulation film over said substrate to cover said active device element;

20 forming a lower electrode layer of said ferroelectric capacitor over said insulation film;

25 forming a ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor;

30 crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere containing a non-oxidizing gas and an oxidizing gas; and

35 forming an upper electrode layer on said ferroelectric film.

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2. A method as claimed in claim 1, wherein said step of forming said lower electrode layer includes a step of depositing a Ti layer and a Pt layer consecutively.

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3. A method as claimed in claim 1, wherein said step of crystallizing said ferroelectric film is

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conducted by setting the composition of said atmosphere such that said atmosphere contains said oxidizing gas with a fraction of 1 - 50% in volume.

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4. A method as claimed in claim 1, wherein  
said non-oxidizing gas is selected from a group  
10 consisting of Ar, He, Ne, Xe and N<sub>2</sub>.

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15 5. A method as claimed in claim 1, wherein  
said oxidizing gas is selected from a group consisting  
of O<sub>2</sub>, N<sub>2</sub>O, NO and NO<sub>2</sub>.

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6. A method as claimed in claim 1, wherein  
said step of crystallizing said ferroelectric film is  
conducted by a rapid thermal annealing process.

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30 7. A method as claimed in claim 1, wherein  
said step of forming said step of forming said  
ferroelectric film comprises the step of forming said  
ferroelectric film by a sputtering process.

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8. A method as claimed in claim 7, wherein

said ferroelectric film has a perovskite structure.

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9. A method as claimed in claim 8, wherein  
said ferroelectric film is a film of zirconate  
titanate of Pb.

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10. A method as claimed in claim 1, further  
comprising the step, after said step of crystallizing  
15 said ferroelectric film, of oxidizing said  
ferroelectric film in an oxidizing atmosphere.

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11. A method as claimed in claim 1, wherein  
said step of crystallizing said ferroelectric film is  
conducted under a reduced total pressure.

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12. A method of fabricating a semiconductor  
device having a ferroelectric capacitor, comprising  
30 the steps of:

forming an active device element on a  
substrate;

35 forming an insulation film over said  
substrate to cover said active device element;

forming a lower electrode layer of said  
ferroelectric capacitor over said insulation film;

forming a ferroelectric film on said lower

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electrode layer as a capacitor insulation film of said ferroelectric capacitor;

5       crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere of an oxidizing gas under a reduced total pressure smaller than an atmospheric pressure; and

      forming an upper electrode layer on said ferroelectric film.

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13. A method as claimed in claim 1 wherein said oxidizing gas is O<sub>2</sub> and wherein said total 15 pressure is set in the range between 1 Torr and 40 Torr.

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14. A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

25       forming an active device element on a substrate;

      forming an insulation film over said substrate to cover said active device element;

      forming a lower electrode layer of said ferroelectric capacitor over said insulation film,

30       said lower electrode layer including a layer part containing Ti atoms;

      forming a ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor;

35       crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere of an oxidizing gas; and

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forming an upper electrode layer on said ferroelectric film,

5 wherein said step of crystallizing said ferroelectric film is conducted by supplying O<sub>2</sub> controlled to cause an oxidation in said Ti atoms reached a surface of said lower electrode from said layer part containing Ti atoms.

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15. A semiconductor device, comprising:  
a substrate;  
an active device element formed on said  
15 substrate;  
an insulation film provided over said  
substrate to cover said active device element;  
a lower electrode provided over said  
insulation film;  
20 a ferroelectric film provided on said lower  
electrode, said ferroelectric film having a columnar  
microstructure extending from an interface between  
said lower electrode and said ferroelectric film in a  
direction substantially perpendicular to a principal  
25 surface of said lower electrode, said ferroelectric  
film essentially consisting of crystal grains having a  
generally uniform grain diameter of less than about  
200 nm; and  
an upper electrode provided on said  
30 ferroelectric film.

35 16. A semiconductor device as claimed in  
claim 15, wherein said crystal grains constituting  
said ferroelectric film have an average diameter of

about 150 nm.

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17. A semiconductor device as claimed in  
claim 15, wherein said lower electrode comprises a Ti  
layer and a conductor layer provided further on said  
Ti layer.

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18. A semiconductor device as claimed in  
15 claim 17, wherein said conductor layer is formed of Pt.

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19. A semiconductor device as claimed in  
claim 17, wherein said ferroelectric film has a  
perovskite structure.

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20. A semiconductor device as claimed in  
claim 19, wherein said ferroelectric film comprises a  
zirconate titanate of Pb.

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